

**ANALYSIS OF ANTI-WASHOUT ADMIXTURE FOR
UNDERWATER CONCRETE**

By

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CERTIFICATION OF APPROVAL

ANALYSIS OF ANTI-WASHOUT ADMIXTURE FOR UNDERWATER CONCRETE

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I hereby certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein has not been, and will not be, submitted elsewhere for publication.

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A project dissertation submitted to the
Civil Engineering Programme
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ABSTRACT

The usage of natural antiwashout admixture for underwater structure in Malaysia is studied for its behavior used as admixture. This study is iterated on finding potential natural antiwashout admixture having similar properties as chemical antiwashout admixture. The significance of this research would be important to find new resource of admixture, reducing underwater construction cost and time. Sample such as starch, and agar will be taken into account for its potential as antiwashout admixture. This research starts by searching for any other relevant journal or article published by other researches and from there, the results would be review and useful information will be summarize and taken as an information to this research.

High-performance underwater concrete (HP UWC) can incorporate a variety of chemical admixtures, particularly AWA and superplasticiser. Most AWAs are water-soluble polymers that increase the viscosity and yield of cement paste and concrete (2, 14). High concentrations of AWA are necessary when the concrete is cast in flowing water, including the surface zone, and when the mix is designed to be highly flowable to spread around obstacles with minimum segregation and water dilution and develop flat surfaces. The experiment is done using selection of ordinary Portland cement, Sikament-100SC antiwashout, starch based antiwashout, and coarse and fine aggregate. For the coarse aggregate the size of aggregate used is passing 20 mm sieve size. The placement of concrete is done by tremie process, dropped and three different heights. For every height three samples of data is taken into consideration. The result of the experiment shows that Sikament has higher compressive strength compared to starch base antiwashout. The strength of concrete samples using starch antiwashout were not affected by the height, dropped from 0.9, 0.6, and 0.4. Samples dropped from lower height yield higher compressive strength than those dropped from 0.9m, and 0.4m. From the result obtained from experiment Sikament 100SC outperformed the natural starch based antiwashout admixture. However the strength of concrete samples that uses starch were not affected by the height of the dropped samples.

TABLE OF CONTENTS

CHAPTER 1 – INTRODUCTION

1.1 Background of study	1
1.2 Problem Statement	2
1.3 Objectives of Report	3
1.4 Scope of study	3

CHAPTER 2 – LITERATURE RIVIEW

2.1 History of Anti-Washout Admixture	4
2.2 Environmental Consideration	6
2.3 Mechanism	6
2.4 Category of Antiwashout Admixture	8
2.4.1 Superplasticiser in Antiwashout Concrete Mixture	10
2.4.2 Properties	10
2.5 Types of Testing Method	13
2.5.1 Stream Test	13
2.5.2 pH Factor Test	13
2.5.3 Plunge Test	14
2.5.4 Spray Test	15
2.6 Admixture (Sikamen 100SC)	16

CHAPTER 3 – RESEARCH METHODOLOGY

3.1 Material Used and Preperation	17
3.1.1 Mixing Admixture into Concrete mix	18
3.1.2 Tank Construction	19
3.1.3 Aggregate Preparation	19
3.1.4 Cube Test	19
3.1.5 Tremie Process	20
3.2 Concrete Mix Design	22

CHAPTER 4 – RESULT & DISCUSSION

4.1 Results	23
4.2 Discussion	26
4.2.1 Strength and Durability	28
4.2.2 Observation	28

CHAPTER 5 – CONCLUSION & RECOMENDATION

5.1 Conclusion	30
5.2 Recommendation	31

CHAPTER 6 – REFERENCES

6.1 References	33
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LIST OF FIGURES

Figure 2.1: Chemical Structure of Welan gum	7
Figure 3.1: Placing the mould into the tank using overhead crane.	20
Figure 3.2: Pumping method	21
Figure 4.1: Compressive strength of concrete using Sikamen 100SC	25
Figure 4.2: Compressive Strength of concrete using starch.	25
Figure 4.3: Comparison of compressive strength of concrete using Sikamen 100SC & starch	26
Figure 4.4: Placing the concrete into the mold	26

LIST OF TABLES

Table 2.1: Classes of Viscosity-Inducing Admixture	8
Table 2.2: Type of water soluble polymers	9
Table 2.3: Criteria of Relationship between Flow ability and Conditions of Execution	12
Table 4.1: Compressive strength at 28 days	23
Table 4.2: Compressive strength at 7 days	24

CHAPTER 1: INTRODUCTION

1.1 Background of study

Underwater concreting is adopted for many offshore activities. The mix proportioning, laying process of underwater concrete and other properties of concrete are very important and it needs investigation especially because the proportioning and properties of the concrete depends very much on the properties of ingredients available in the local region. In the construction of offshore structures, under water concreting play an important role.

Underwater concrete may be used to fill pre-excavated holes in the sea floor. It may be used to repair the submarine pipeline, if it is leaking by pouring underwater concrete onto the damaged location. It may be places in piles to give added structural strength and to prevent buckling. Under water concrete can be used to stabilize the pipelines laid on the sea floor. There has also been growing interest in use of concrete with the presence of antiwashout admixture (AWA) for underwater structural repairs.

Welan gums are some of the AWA used in underwater concreting. The material is long-chain polymers and has high molecular weight of approximately 2 million grams. Others such as starch and agar are two materials that have approximate properties as chemical AWA's. In the case of underwater concreting operations, mix design plays a significant part in the overall efficiency of construction in terms of technological quality and overall economics. Almost without exception trial mixes will be required.

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1.2 Problem Statement

The aims of this study are as follows:

This project is aim to find natural material that is cheap and widely available to be used as AWA replacement. Experiment shall be done to demonstrate the process of underwater concreting in and to determine the compressive strength of underwater concrete incorporating AWA. There is need to do more research since underwater concreting is still new. Properties of concrete from the concrete poured underwater after specified number of days is also determined by doing research and experiment.

The research is limited to study the effect of natural materials on compressive strength of

In this experiment the washout of cement paste if observed to find the major loses in underwater concreting. This experiment determines the effectiveness of the antiwashout used in construction phase. Chemical based anti washout chemical are costly thus a substitute material that is cheap and widely available. Apart from that there are very few company that manufacture antiwashout admixture naturally there is no competitors in the industry. Thus, allowing for fixed high price of chemical based antiwashout admixture. The chemical based antiwashout manufactured are also non homogenous.

For this study, the following parameters considered as the test parameters:

Huge construction companies may be able to find antiwashout admixture manufactured outside of Malaysia and giving them more option for construction. However, it will incur more cost and also foreign companies gain twice profit due to lack of competition in manufacturing the admixture. The chemical based antiwashout are also non homogenous.

• *Construction*

The final quality of the concrete depends not only on fluctuations in the quality of the materials and measurement errors, but also on the effects of underwater drop height, underwater flow distance, and water currents in the area of construction, consideration should also be given to these points. This comes back to the quality of antiwashout underwater concrete is greatly affected by the construction conditions as well as the materials used and the mix proportion. Thus it is important that these factors be comprehensively considered if a structure of the required performance is to be obtained.

1.3 Objective

The objectives of this study are as follow:-

- To find alternative to chemical antiwashout, Sikament 100SC using natural starch based Antiwashout admixture that can be found locally.
- To indentify the compressive strength of concrete cast underwater using starch.

1.4 Scope of study

This research is limited to study the effect of washout towards the compressive strength of underwater concrete incorporating Sikamen 100SC and natural starch based antiwashout. This research is taking into consideration the following parameters:-

- Experiment done is limited to fresh water and still water.
- Each sample will be repeated three times to reduce human error and to achieve better results.
- Every sample will be dropped from height of 0.9 m, 0.6m, and 0.4 m.

For this study, the following parameters are considered in the mix proportions:-

- Ordinary Portland cement (OPC)
- Sikamen 100SC
- Natural starch based antiwashout
- Water
- Coarse aggregate
- Fine aggregate

In this experiment baffle tank that is located at Block J is used to conduct the experiment. After the construction of tank, preparation of the aggregates is needed by sieving the aggregates. The aggregates are then soaked in water and left to dry for approximately one day at room temperature. Sieve analysis done to ensure that all sizes of the aggregates are being graded well. The experiment is done based on the different weight of the aggregates according to the sizes.

CHAPTER 2: LITERATURE REVIEW

2.1 HISTORY OF ANTIWASHOUT ADMIXTURE

AWA first appeared in Germany in the mid-1970s and in Japan in the early 1980s. They have also been used since the late 1980s in North America. Recently, interest has grown in high-performance concrete containing anti-washout admixture for casting and repairing submerged structures. Flowing AWA concrete has been used to repair the bases of stilling basins and hydraulic canals damaged by abrasion-erosion [1].

Nowadays, underwater concreting are becoming widely used in repairing underwater structures. Mega bridges and offshore structures are being built and the cost of maintaining the structures especially underwater is becoming a challenge. This is due to the presence of erosion that is found in most of underwater structures. Repairing them would require immense work because casting concrete requires dry surrounding. With the development of AWA, process of casting concrete underwater can be done.

The stability of fresh concrete is characterized by its resistance to washout loss, segregation and bleeding and is affected by the mix design, aggregate shape and grading, impossibility of compaction by vibration and conditions of placing. When a mix is not sufficiently stable, the cement paste may not be cohesive enough to retain individual aggregate particles in a homogeneous suspension. The constituents therefore separate, significantly reducing the mechanical properties and durability of the hardened concrete.

Concrete cast underwater, differential velocity at the interface between freshly cast concrete and surrounding water can erode cementitious materials and other fines. Such erosion increases turbidity and contamination of the water and impairs strength, bond to reinforcement and other surfaces, and durability (1). Several researchers have related the improvement in properties of underwater-cast concrete and grout to better washout resistance (2,3).

ENVIRONMENTAL CONSIDERATIONS

Recently, interest has grown in high-performance concrete containing anti-washout admixture for casting and repairing submerged structures. Flowing AWA concrete has been used to repair the bases of stilling basins and hydraulic canals damaged by abrasion-erosion. Such repair often necessitates casting thin lifts of concrete that can prevent the maintenance of a continuous seal at the bottom of the placing device such as a tremie, normally required to minimize segregation and water erosion of freshly cast concrete.

Flowing AWA concrete can be useful for casting concrete in water where poor visibility prevents divers from ensuring the continuous seal at the bottom of the placing device. Highly flowable AWA concrete is used to fill sections of complex geometry where the concrete is expected to spread readily without external compaction around boundaries of formed areas and reinforcement to give flat surfaces with sound mechanical properties. AWA concrete is used for casting conventional tremie concrete for cofferdam seals to produce flowable flat surfaces of high in-situ quality.

Improving the washout resistance of concrete helps underwater placing where high strength, durability and bond to steel and adjacent surfaces are required. Casting a fluid yet washout-resistant concrete is especially advantageous in structural repairs. Reducing the fluidity of the mix can enhance the resistance of a concrete to dispersion by water. However, this can limit the ability of the cast material to spread readily into place and around obstacles. By selecting an efficient dosage and type of anti-washout admixture (AWA) also known as viscosity-modifying admixture and superplasticiser - it is possible to produce a highly fluid and washout-resistant system that can be cast underwater without compaction.

2.2 ENVIRONMENTAL CONSIDERATION

The antiwashout admixtures are not known to be hazardous materials. Since concrete with these admixtures is more cohesive and less susceptible to washing out of cement fines during an underwater concrete placement, the water quality should be affected to a lesser degree than if the admixtures were not used. If a significant amount of cement washes out of the concrete in a small body of water, the pH of the water can be increased slightly[8,9].

Whether this increase, if it should occur, will result in unacceptable water quality or other undesirable environmental consequences should be evaluated on a project specific basis. Personnel familiar with evaluation of water quality impacts of construction operations should be consulted during the early stages of project planning to ensure that appropriate water quality criteria and other environmental regulations will be met.

2.3 MECHANISM

The anti-washout admixtures produce open-branched polymer network in the water, which locks together the mix water, cement and sand. This reduces the tendency for dilution with external water during and after placing. The cohesion of the mix is increased, reducing workability and flow. Common AWAs include cellulose derivatives and polysaccharides from microbial sources – such as welan gum – that bind some of the mixing water, enhancing viscosity. An example of currently used AWA is being market in Japan. One of the most commonly used is welan gum.

These AWA have cellulose or acrylic as the main ingredient. The acrylic admixture has a polyacrylamide polymer as its main ingredient. The cellulose admixture is non-ionic water-Soluble cellulose ether (Figure 1). It has an hydroxide ion (OH) base which is almost similar to water [1,2.]. Some other admixture that is used is hyroxypopylmethylcellulose (HPMC),

hydroxyethylmethylcellulose (HEMC), and hydroxyethylcellulose (HEC). These admixtures's viscosity, when dissolved, differs with respect to polymerization, molecular weight and also type of substituent. They dissolve rapidly in a mixture of high pH such as concrete. Their properties are not prone to chemical changes within concrete as reaction, gelation or decomposition. AWA are more effective if the base mix is cohesive.

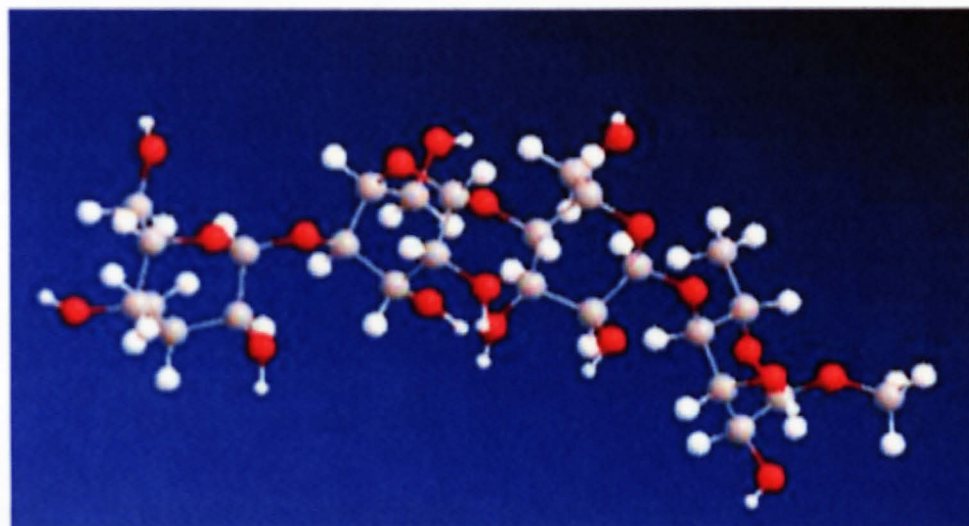


Figure 2.1 Chemical Structure of Welan gum

2.4 CATEGORY OF ANTIWASHOUT ADMIXTURE

Materials that have been used as viscosity-inducing admixture may be classified according to their physical action as follows.

Table 2.1: Classes of Viscosity-Inducing Admixture

Class Type	Description
Class A	Water soluble synthetic, which increase the viscosity of the mixing water. They include cellulose ethers, pregelatinized starches, polyethylene oxides, alginates carrageenans, polyacrylamide, carboxyvinyl polymers and polyvinyl alcohol.
Class B	Organic water-soluble flocculants, which are absorbed on the cement particles and increase viscosity by promoting interparticle attraction. These material are natural gum, styrene copolymers with carboxyl groups and synthetic polyelectrolyte.
Class C	Emulsion of various organic materials, which increase interparticle attraction and also supply additional superfine particles in the cement paste. These material consist of acrylic emulsion and aqueous clay dispersion.
Class D	Inorganic material having high surface area which increases the water-retaining capacity of the mix. They include very fine clays (bentonites), pyrogenic silicas, condensed silica fume. Milled asbestos and other fibrous materials.
Class E	Inorganic material, which supply additional fine particles to the mortar pastes and thereby increases the thixotropy, such as fly ash, hydrated lime, kaolin and various rock dusts.

The increase viscosity of water in the mix results in a grater thixotropy of the concrete and an improved resistance to segregation. Dosage of the admixture for classes A, B and C range from 1-1.5% by weight of the water in the mix. Superplastiziser is incorporated to the mixing of concrete paste. The magnitude of the thickening effect produced is dependent on the admixture dosage and molecular weight of main component [4, 5].

Materials in classes D and E influence the void structure by acting as pore fillers, although the increased fines content often increases lubrication of the mix. However only a few can be consistently combined with water reducing admixtures and superplasticizers to produce concrete with cohesive yet highly flow able mixture.

The types of water-soluble polymers use for thickening cement slurries, mortar and concrete are shown in Table 2.2. Not all the polymers shown below can be use to increase the viscosity of the water in mix. This is because not all are pseudoplastic polymers compatible with cement systems.

The primary structures of class A materials is that of a backbone of six carbons chains with side chains. They are high molecular weight materials that build viscosities in solution via hydrogen bonding. However certain materials which lack significant hydrophobic substituent (such as high molecular weight polysaccharides) are more tolerant of salt and cations, stable to changes in pH and temperature, and do not generate foam [6].

Table 2.2: Type of water soluble polymers

Natural	Semi-synthetic	Synthetic
Starches	Hydroxypropyl methylcellulose (HPMC)	Polyvinyl alcohol (PVA)
Guar gum	Hydroxyethyl cellulose (HEC)	Polyethylene Oxide (PEO)
Locust bean gum	Carboxymethyl cellulose (CMC)	Polyacrylamide
Alginates	Propylene Glycol Alginate (PGA)	Polyacrylate
Carrageenans	-	Polyvinylpyrrolidone
Agar	-	-
Arabic gum	-	-
Tragacanth gum	-	-
Xanthan gum	-	-
Welan gum	-	-

2.4.1 Superplasticiser In Antiwashout Concrete Mixture

A superplasticiser is usually incorporated with the AWA to enhance workability and avoid the need to increase w/cm ratio. Regardless of the required consistency and w/cm ratio, a proper combination of AWA and superplasticiser can significantly enhance washout resistance. This can improve the ability of the paste to retain mixing water, suspend aggregate homogeneously, and fill congested structural sections.

The production of non-dispersible colloidal underwater concrete, minimum water-cement ratios range from 0.36 to 0.40, and cement, with fine aggregate contents are higher than corresponding mixes. To adjust the mixture to obtain desired design parameters for all properties is difficult. The use of AWA and superplasticizer, such as silica fume or conventional water reducers can reduce segregation. The key to non-dispersible concrete with self-leveling characteristics is the successful optimization of the AWA with the superplasticizer to increase the slump.

2.4.2 Properties

High concentrations of AWA are necessary when concrete is cast in flowing water. This includes the surface zone and when the mix is designed to be highly flowable to spread around obstacles with minimum segregation, water dilution, and develop flat surfaces. Superplasticiser is usually incorporated with AWA to enhance workability and avoid the increase water to cement (W/C) ratio.

Such repair often necessitates casting thin lifts of concrete that can prevent the maintenance of a continuous seal at the bottom of the placing device such as a tremie, normally required to minimize segregation and water erosion of freshly cast concrete. Flowing AWA concrete can be useful for casting concrete in water where poor visibility prevents divers from ensuring the continuous seal at the bottom of the placing device.

Highly flow able AWA concrete is used to fill sections of complex geometry where the concrete is expected to spread readily without external compaction around boundaries of formed areas and reinforcement to give flat surfaces with sound mechanical properties. AWA concrete is used for casting conventional tremie concrete for cofferdam seals to produce flowable flat surfaces of high in-situ quality [4].

Incorporating AWA into concrete may increase the yield stress and also the plastic viscosity of the cement [1.]. The statistical experimental design method is rigorous technique for both achieving desired properties and establishing an optimized mixture for the given constraint while minimizing the number of trials. Neeley [3] reported on evaluation of concrete mixture for use in underwater repair. He included concrete made with five different antiwashout admixtures. He found that all had a beneficial effect but none stood out as better than the other.

The incorporation of fine material can also add to the increase of viscosity in cement paste. High-performance underwater concrete (HP UWC) can incorporate a variety of chemical admixtures, particularly AWA and superplasticiser. Most AWAs are water-soluble polymers that increase the viscosity and yield of cement paste and concrete. High concentrations of AWA are necessary when the concrete is cast in flowing water, including the surface zone.

Mortar and concrete mixed with cellulose ether have greatly increased air content. In this case an air-detraining can be added to the AWA to reduce air content of the concrete between 3%-5%.the bubble spacing factor of concrete with the antiwashout admixture is the same as concrete without the admixture.

The setting time of concrete is affected by cellulose admixtures. When simple cellulose is used, setting time is greatly retarded. Consequently, an accelerator is included in the antiwashout admixture. The most common admixture amounts are adjusted to result in a setting time of from 5 to 12 hours. Acrylic admixtures have virtually no effect on the setting time.

When an air-entraining, water-reducing admixture is added to the antiwashout admixture, the setting time is somewhat retarded, but the retardation time for the usual admixture amounts is less than five hours. Also, there is a retarding admixture that makes the initial setting time about 30 hours that can be used to prevent cold joints during construction.

The dispersion resistance of concrete during underwater placement is evaluated by such things as the cement outflow rate, the change of water permeation rate, the turbidity of the water, the change of the pH value, and the change of composition. The rate of dispersion is decreased as the anti-washout admixture is increased.

Table 2.3: Criteria of Relationship between Flow ability and Conditions of Execution

Slump Flow Value (cm)	Softness	Condition for Application and Condition for Execution
40	Hard consistency	When it is desired to keep the flow small, such as the execution of slanted path.
45	Medium consistency	General case, less than 50m concrete pump pressure transmission distance.
50	Medium consistency	When excellent filling capability is needed
55	Soft consistency (plastic concrete)	Excellent flow ability is need, such as reinforced concrete members of dense fiber and filler for narrow and deep holes.

2.5 TYPES OF TESTING METHOD

A standard, accurate, reproducible and meaningful test for assessing the effectiveness of AWAs has been sought for some years. A number of tests have been proposed and are used, but no international standard for AWA performance has been established. It is important to be able to evaluate the effects of non-dispersible concrete admixtures not only in terms of obvious short-term parameters but also their influence in the longer term and over the full life of the structure. Tests are required to evaluate segregation resistance, workability/flow, chemical compatibility, influence of admixtures on strength and effectiveness at full-scale.

2.5.1 Stream test

The simple stream test, developed in Belgium (12), gives a visual assessment of the degree of washout resistance. It can be used in a laboratory and on site. A 100-150mm diameter guttering channel 2m long is set at a slope of 15 to 20 deg to the horizontal and a concrete sample is placed 300mm from the raised end. Water is poured down the gutter and over the sample and the washout assessed visually.

Although useful, it is strongly operator-sensitive because of the rate at which the water is poured: obviously, the faster the water flow, the greater the washout. Operators must therefore have substantial previous experience if results are to be useful. It is important that the same volume of water is poured down the channel from the same point each time.

2.5.2 pH Factor Test

The pH factor test was proposed in a Japanese recommendation (2). A fresh concrete sample is separate into several parts and then drop into a beaker fill with water. After three minutes, a unit volume of the supernatant solution is put into another beaker. The pH of this solution, rounded to one decimal place, is then determines and recorded. High pH, would result in high cement washout.

2.5.3 Plunge test

The plunge test was originally used at the University of Ghent in Belgium. This involved a small basket with 3mm diameter holes, the basket of concrete being immersed in water three times. The loss of mass due to washout was then determined, in the same manner as in the CRD C61(7) test, which was adopted by the US Corps of Engineers as its internal standard.

The CRD C61 test involves filling a standard perforated basket with 2.2 ± 0.2 kg of fresh concrete and dropping it three times through a 1.7-m high column of still water(7). Again, the holes in the basket were 3mm diameter. The sample is left at the bottom for 15 seconds after each drop, before being slowly retrieved. The loss of mass provides a quantitative result

Experiments at the University of Paisley showed that the CRD C61 test had serious limitations. It was possible to get apparently good washout resistance simply because the aggregates in the mix partially blocked the holes (8). The test was therefore modified to use a bigger basket with larger (20mm) holes and immersions were increased from three to five. However, with highly flowable concrete similar to mixes used for underwater placement, some concrete invariably flowed out through the holes before any immersions took place (8).

At a nuclear facility where unreinforced mass underwater concrete was placed(9), the tendency for mortar washout was assessed by dropping a basket containing about 5kg of concrete through a column of water 0.75m high and measuring the loss of mass. As the concrete was to be placed into static water within a cofferdam, the test was considered to be more rigorous than the actual placing requirements but nevertheless suitable for comparisons (9).

2.5.4 Spray test (MC-1)

The spray test MC-1, developed by Ceza at the University of Paisley(8,10,11), directly determines the resistance to washout of a concrete mix to produce quantitative results. In the test, a mould filled with a weighed sample of around 1kg of fresh concrete is placed on a base-plate. The mould is removed and the base-plate plus sample is put on a frame suspended from an electronic balance.

A computer is connected to the balance and set in a mode in which an increase in pressure on the base-plate by the water spray switches on the recording of the washout process. Recording begins automatically when the tap on the pipe supplying water to the tank with the spray-head is opened. Water from the spray-head washes out the sample for 4 minutes. A constant head of water in the tank maintains uniform pressure throughout the test.

The measurement recorded directly from the balance every 2 seconds corresponds to the mass of the sample resting on the base-plate and the 'mass' due to pressure and volume of the water sprayed onto the sample. The amount of material lost is obtained automatically as the effect of the pressure and mass of the poured water is subtracted from the direct measurement from the balance.

A calibration procedure, in which a mock-up of the hardened concrete sample is used instead of the fresh concrete, provides the combined values of the pressure and mass of the water on the sample. Figure 4 gives an example of the effect of the anti-washout admixture dose on the washout loss measured by the MC-1 test (10). Washout is expressed as a percentage of the mass lost compared to the original mass after 4 minutes (10).

The test is applicable to underwater concrete, where the slump and slump flow are less than 240mm and 450mm respectively. Highly flowable concrete is difficult to test as it would tend to flow off the base-plate (8).

2.6 ADMIXTURE (SIKAMEN-100SC) FIELD METHODOLOGY

In this experiment Sikament-100SC is used as a control sample. It is a unique biopolymer anti-washout admixture for the underwater placement of concrete and grout. Sikament®-100SC increases mix cohesiveness and imparts a variable viscosity characteristic to concrete and grout. It produces concrete that becomes fluid and flowable when sheared or mechanically agitated such as during pumping operations.

This characteristic enables concrete to flow easily through and into mould or confined spaces. The mix will revert to a dense, high viscous, consistency when at rest. This cohesive cement paste matrix promotes high compressive and flexural strength development.

Sikament-100SC is widely used for underwater placement of concrete and grout in fresh and saltwater environments. Sikament-100SC improves underwater “stacking” characteristics when concrete is placed by tremie operations. The ability of concrete mixtures to penetrate and consolidate foundation rock layers is dramatically improved, for example, as required in jetty sealing operations.

Sikament-100SC reduces or eliminates the need to dewater underwater construction sites before concrete construction can take place. Concrete can be placed by pump or tremie directly into areas covered by water. Sikament-100SC maintains the concrete matrix integrity during high slump placements and reduces washout from the surface during curing.

- Reduce or eliminate dewatering costs associated with underwater construction
- Concrete is easy to pump and flows readily into available spaces
- Segregation and dilution are reduced, in-place compressive and bond strengths are significantly increased
- Laitance on concrete surface caused by cement paste washout during curing is reduced or eliminated
- The active slump life of the concrete is doubled without extended delays in setting time

CHAPTER 3: RESEARCH METHODOLOGY

3.1 MATERIAL USED AND PREPERATION

In this experiment the type of antiwashout used is Sikamen 100SC and using starch based natural antiwashout admixture. The first step is to determine the proportioning of mixing, amongst the materials required for these experiments are;

- **Coarse aggregate passing 20mm sieve:** In this project, coarse aggregate type used is crushed aggregate with maximum size of 20mm according to BS 812-103.2 1989 [21]. The coarse aggregates are prepared as Saturated Surface Dry (SSD) by washing the aggregates prior to mixing process. The use of SSD aggregate is to avoid the aggregate from absorbing water in the polymeric concrete mix. Rounded aggregates achieve more dense packing and can reduce water demand for a given degree of workability than crushed rock aggregates. The usage of rounded aggregates will increase cohesion for a given sand friction and cement content and to have a reduced tendency to segregation and bleeding. When strength and abrasion are significant parameters, extra care of selecting the overall grading is needed.
- **Fine aggregate:** In underwater concrete there should be a significant proportion of a particle size less than 300 μm . For this experiment standard ASTM C117 - 04 is used to obtain fine aggregate less than 75- μm (No. 200). At least 15-20% of the sand fraction should pass a 300 μm sieve as this is necessary to enhance the cohesive properties of concrete to be placed under water. For fine aggregate, natural sand with maximum size of 5mm will be use to produce polymeric concrete.
- **Ordinary Portland cement (OPC):** Using type 1 OPC or type 1 Portland cement stated by ASTM C150 shaving not more than 10% C^3A is suitable for underwater concrete construction where the sulphate content (expressed as concentration of SO^3) of ground water does not exceed 1200 parts per million (ppm), and for marine structures which are permanently submerged.

- **Anti-washout admixtures:** In this experiment the types of antiwashout used are Sikamen 100SC and natural starch based antiwashout. Antiwashout can be used to reduce the risk of segregation and washout with the tremie methods of placement, improve self-compaction and flow properties. This allows the placement of concrete to be fast and less difficult place.
- **Water**

The materials are obtained from local construction company in Bota. However for Sikament 100SC was obtained from Sika kimia Sdn. Bhd. The amounts of chemical given were sufficient to do the experiment. As the product is expensive the author requested the company to allow giving samples of the product for educational purposes.

3.1.1 Mixing Admixture into Concrete mix

The AWA used are water soluble polymers that increase the viscosity of the mix and hence the washout resistance and segregation. For this experiment the usage of Sikamen 100SC is used as a control sample. The cement dosage of 420 to 520 Kg/m³ and the concentration of 0.02% to 0.13% for anti wash out admixture are used. Water cement ratio is 0.43. Anti washout admixture is utilized to increase the viscosity of concrete is increased and the resistance to wash out is increased.

After the concrete is made using a trial proportion as given above, the workability and compressive strength of concrete is determined (as normal concrete is found out) A slump of 180 mm to 200 is suitable. The admixture is added to the fresh concrete after all the other ingredients have blend in. Addition of the admixture to early might promote the clumping of the material. It is best to use mixer that is capable to shear the material and the entire component.

3.1.2 Tank Construction

One of the major facilities of the experiment is the tank a pressed steel plates of size 1m x 1m x 1m are available in the market. A bottom plate of 1m x 1m is provided at the base and four plates are connected around to form first layer of tank. Now the tank will be of size 1m x 1m x 1m. Above this two more layers of plates are connected to complete the tank of size 1m x 1m x 3m on the whole 13 plates are required. However for this experiment a tank of 1m x 1.5 x 2.5m is being used as the construction of tank might take most of the cost.

3.1.3 Aggregate Preparation

After the construction of tank, preparation of the aggregates is needed by sieving the aggregates. The aggregates are then soaked in water and left to dry for approximately one day at room temperature. Sieve analysis done to ensure that all sizes of the aggregates are being graded well. The experiment is done based on the different weight of the aggregates according to the sizes. The aggregates sizes that is obtain vary from less than 3.35mm to more than 20mm. The retained aggregate at each sieve will be separated according to the grade and aggregate that retained on the last pan will be considered as fine aggregates because the size is less than 3.35mm.

3.1.4 Cube Test

To test the underwater concrete strength three cube moulds inside are kept at the base of the tank. Fill the tank with 1m water depth. The concrete is poured through 0.9 m water from a tube with conical onto the cube moulds to be filled. Once the three cube moulds are filled by concrete falling exposed through water, lift and take out the cube moulds with concrete outside the tank and level the top with a ruler and can be kept back at the bottom of the tank.

After 28 days, the cube moulds are taken out and the cubes are tested as usual to find the strength. The mix proportion can be change using different amount of admixtures to get higher strength and better workability. To simulate underwater concreting the tank is filled with fresh water. To simulate underwater concrete in sea, the tank can be filled with sea water.

The steps above can be incorporated with other types of AWA sample with respect to the aggregate and W/C ratio. A chart is best use to describe the progress of this research (Figure 3). Towards the end of the first part of this research the author is able to present the progress of the research that has been done.

3.1.5 Tremie Process

This process is a simple process whereby dry pipe technique is employed for starting the tremie pour. As the pipe is lowered to rest on the bottom, water pressure seals the gasket and the pipe is kept dry. In very deep placements, an open-ended pipe can be set and a go-devil or traveling plug inserted to keep water from penetrating the first concrete placed in the pipe. All vertical movements of the tremie pipe must be done slowly and carefully to prevent a loss of seal.

However for this project some of the method had to be modified. The mould is placed on a ramp, using an overhead crane the mould is lowered into the tank (Figure 3). Safety equipment is a must while handling these cranes.



Figure 3.1: Placing the mould into the tank using overhead crane.

Another method that is popular is the pumping method (Figure 4). This method uses the mechanical aid of a pump to place concrete into the mould. This method is more effective and requires less man power to deal with. However this method requires more supervision as the pump might malfunction.

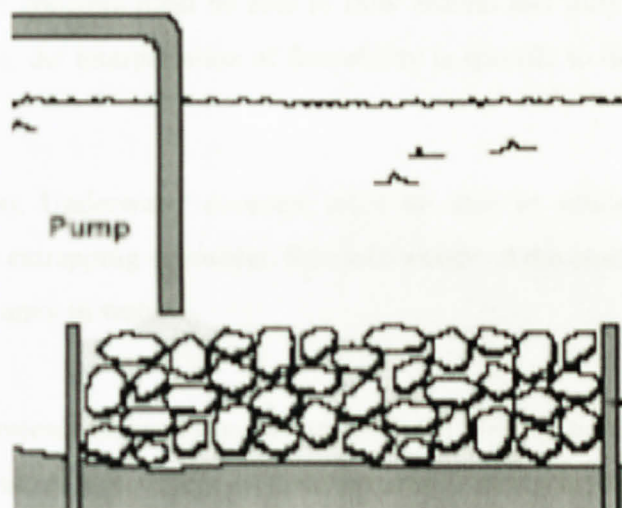


Figure 3.2 Pumping method.

If loss of seal does occur, the tremie must be brought back to the surface, the end plate must be replaced, and flow restarted. A go-devil must not be used when restarting a tremie after a loss of seal. Water pushed out by the go-devil will wash cement out of the previously placed concrete. Concrete placement should be as continuous as possible through each tremie. Longer delays must be treated by removing, resealing and restarting the tremie.

However dispersion resistance could be high, blockage will occur only if there is difficulty within the pressure transmission tube during the pumping pressure period. Moreover, there will be hardly any qualitative changes to the concrete before or after the pressure is transmitted. However, because of high viscosity, pressure transmission resistance is 2 to 4 times that of ordinary concrete.

3.2 CONCRETE MIX DESIGN

Concrete placed underwater is inherently susceptible to cement washout, segregation, cold joints, and water entrapment it must possess properties that are not otherwise required. The following list outlines the essential and unique requirements for concrete placed underwater [15, 16]:

- **Flowability:** the concrete must be able to flow around and fully encase reinforcing steel bars. In practice, the interpretation of flowability is specific to the application for a given project.
- **Self-compaction:** Underwater concrete must be able to solidate itself under its own weight without entrapping any water. The self-weight of the concrete should substantially reduce its buoyancy in water.
- **Adequate cohesion:** Cohesive concrete prevents segregation, excessive bleeding or cement wash-out. A high degree of cohesiveness in concrete improves homogeneity and strength of the underwater concrete. However the degree of concrete cohesion depends on many variable of the project.
- **Adequate in-place concrete strength:** The mix design should account for some inevitable wash-out of cement by water during concrete placement, which leads to loss of in-place concrete strength [16]. Use of silica fume and anti-washout admixtures is also very effective for increasing in-place concrete strength [15].

CHAPTER 4: RESULT AND DISSCUSSION

4.1 RESULTS

Table 4.1 shows the compressive strength of concrete using Sikamen 100SC shows a notice able compressive strength value. The highest compressive strength value for sikamen 100SC sample is 31.27Mpa at 28 days. The lowest compressive strength value for same sample is 23.43Mpa at 28 days. Samples using starch has a compressive strength of 22.45Mpa at 28 days. The lowest compressive strength for starch sample is 20.11Mpa at 28 days (Table 4.1). The results obtained can be used to compare the difference of strength of sample dropped from height of 0.9m, 0.6m, and 0.4m.

Table 4.1: Compressive strength at 28 days

Height (m)	Cube No.	Strength 28days (Mpa)	
		Sikamen-100SC	Starch
0.9	1	25.41	21.78
0.9	2	25.67	21.18
0.9	3	23.71	20.11
0.6	4	26.32	21.67
0.6	5	26.33	21.56
0.6	6	23.43	20.33
0.4	7	31.27	22.45
0.4	8	30.33	22.13
0.4	9	29.51	22.51

Table 4.2 shows the compressive strength of concrete samples using sikamen 100SC, and starch based antiwashout. The highest compressive strength for sikament sample is 21.66Mpa at 7 days and the lowest compressive strength value is 15Mpa at 7 days. The highest compressive strength for concrete using starch is 16.24Mpa at 7 days and the lowest value is 13.28Mpa at 7 days (Table 4.2). The strength of the starch for 7 and 28 days were consistent. There differences of value were not huge compared to concrete using sikamen 100SC. Concrete that did not use any AWA could not achieve the required strength this maybe be due to the heavy washout caused when pouring the concrete into the mould.

Table 4.2: Compressive strength at 7 days

Height (m)	Cube No.	Strength 7 days (Mpa)	
		Sikamen 100SC	Starch
0.9	1	16.0	13.81
0.9	2	16.68	14.06
0.9	3	15.0	13.75
0.6	4	16.37	14.56
0.6	5	18.72	15.54
0.6	6	15.86	13.28
0.4	7	19.22	15.42
0.4	8	22.55	16.24
0.4	9	21.66	15.89

Figure 4.1 shows the result of the compressive strength for concrete using Sikamen 100SC. Every sample was dropped from different height. Concrete sample that is dropped from 0.4m has higher compressive strength than sample that is dropped from 0.9m. Figure 4.3 is a combination of results obtained from figure 4.1 and figure 4.2. The graph shows similar trend whereby

samples dropped from height of 0.4m gives the highest compressive strength followed by 0.6m, and 0.9m gives the lowest strength.

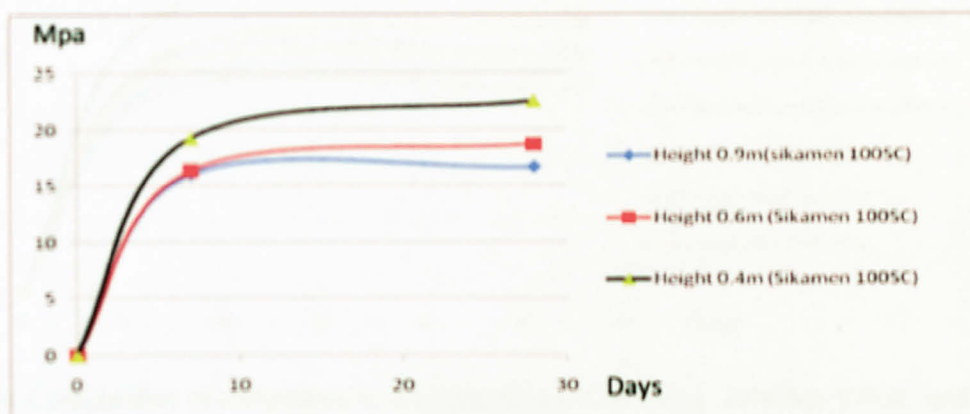


Figure 4.1: Compressive strength of concrete using Sikamen 100SC

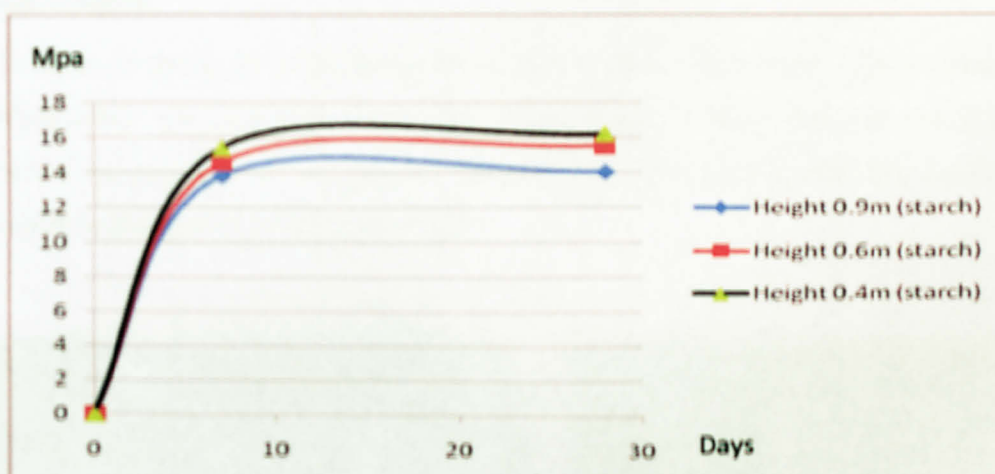


Figure 4.2: Compressive Strength of concrete using starch.

In figure 4.3 the value of compressive strength for concrete sample using starch recorded a lower value compared to samples using sikamen 100SC. Concrete using the chemical AWA also reaches higher compressive strength after 7days of curing. At 28 day of curing all three sample using sikamen obtained higher strength than starch based samples.

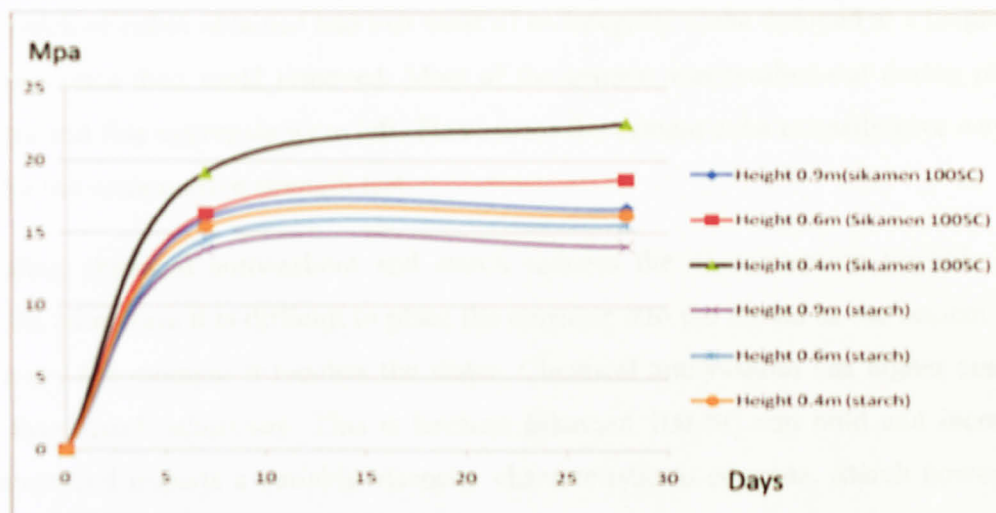


Figure 4.3: Comparison of compressive strength of concrete using Sikamen 100SC and starch

4.2 DISSCUSION

During the course of doing the experiment there few modifications made during pouring the concrete. Workability was one of the issue that caused huge problem, thus for best result the concrete should be prepared in a concrete mixer. This is to ensure that the samples are thoroughly shear and blend all of the components

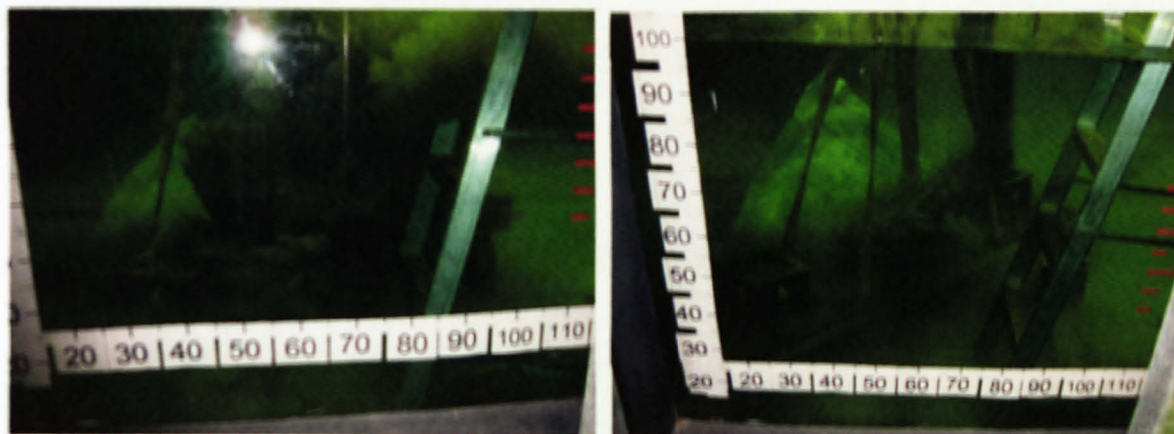


Figure 4.4: Placing the concrete into the mold.

The first batch of cubes obtained had lost most of its integrity. Cube dropped at a height of 0.9m disintegrates once their mold removed. Most of the cement was washed-out during placement, only coarse and fine aggregate were left. This causes the cement cube to easily give way and not suitable for the compressive strength test.

Incorporating chemical antiwashout and starch reduces the contamination towards the tank. Without the admixture it is difficult to place the concrete into the mould as the cement would be washed away the moment it touches the water. Chemical antiwashout has higher compressive strength than starch admixture. This is because Sikamen 100 SC can hold and increases mix cohesiveness and imparts a variable viscosity characteristic to concrete. Starch however reacts with water making some of the paste unable to hold the aggregate together.

Some of the measures used to enhance washout resistance involve reducing water/cementitious materials (w/cm) ratio, increasing cementitious material content, adding silica fume, pfa and other fines, incorporating an AWA, and reducing fluidity [3]. A large decrease in aggregate volume or increase in water content can lower the cohesiveness and lead to wet segregation. A high sand-to-total aggregate content of 42-50% is often used to enhance cohesiveness and reduce the risk of segregation and dispersion in water (3, 14).

Superplasticiser is usually incorporated with the AWA to enhance workability and avoid the need to increase w/cm ratio. Regardless of the required consistency and w/cm ratio, a proper combination of AWA and superplasticiser can significantly enhance washout resistance. This can improve the ability of the paste to retain mixing water, suspend aggregate homogeneously, and fill congested structural sections.

The ratio of tensile strength and flexural strength to compressive strength of an underwater-made test specimen is virtually identical with that of an air-manufactured test specimen of ordinary concrete. The modulus of elasticity is the same or slightly less than that for ordinary concrete. The unit volume of water for antiwashout underwater concrete is much greater than that for ordinary concrete. Because water retention is high, drying shrinkage is great at 20-35 percent. Moreover, air creep appears to be somewhat greater than for ordinary concrete.

The amount of admixture to be incorporated is determined by the flow ability needed; distance placed underwater, horizontal flow distance, and such proportional conditions as water-cement ratio and unit cement content. In general, the compressive strength ratio is fixed to be from 0.8 to 0.9.

4.2.1 Strength and durability

There is also evidence of the durability of non-dispersible concretes containing cellulose ether, and acrylic latex has been used to enhance the properties of hydraulic cement concretes (at much higher proportions than are used in non-dispersible concretes) for well over 10 years. The long-term durability is not therefore likely to be reduced by the use of these admixtures and, in view of the more reliable quality achieved durability is likely to be enhanced [17].

Production of cubes by dropping concrete into moulds placed in water tanks is the most common approach but does not readily simulate practical conditions. A better approach is to produce 300mm diameter castings in moulds which include simulated reinforcement. These need to be sufficiently large to enable 100mm diameter cores to be cut to provide the test specimens.

The long-term durability of concrete containing the normal range of admixtures is well established. Less direct evidence is available for non-dispersible admixtures, particularly in terms of synergistic effects. However, the addition of micro silica to enhance the strength and durability of concrete has become established practice [4].

4.2.2 Observation

Cube having no AWA did not have any show any strength and that is because of loss in cement paste during the pouring of the cement. The samples using starch however had lower compressive strength at day 7 compared to cubes using Sikamen 100-SC. However the difference was not big at 7 day compressive strength. The strength of concrete using starch admixture was not affected by the height it was dropped from 0.9m, 0.6m, and 0.4m.

For Sikament 100SC there is significant changes of compressive strength when drop dropped from different height. The process used in this experiment is almost near or an approximate to tremie process. The concrete is poured into the cube channeled by dry pipe. At the end of the pipe is the mould and once the pipe is in place the concrete is poured into the mould. The first sample poured into the tank clouded the tank making the water filled with washed-out cement.

This causes the tank to be murky making it difficult to pour the concrete. Then the author chooses to wait until the tank is partially clear for observation to be made. While removing the mould, some of the concrete paste was also washed away during the process. This made the integrity of the concrete to be greatly reduced

High-performance underwater concrete (HP UWC) can incorporate a variety of chemical admixtures, particularly AWA and superplasticiser. Most AWAs are water-soluble polymers that increase the viscosity and yield of cement paste and concrete (2, 14). High concentrations of AWA are necessary when the concrete is cast in flowing water, including the surface zone, and when the mix is designed to be highly flowable to spread around obstacles with minimum segregation and water dilution and develop flat surfaces.

CHAPTER 5: CONCLUSION & RECOMMENDATION

5.1 CONCLUSION

Now in the second phase of the project, lab works are done. Results were obtained and the author finds that concrete that the first batch of concrete poured lost its integrity due to heavy washout. From the table obtained concrete that is mixed with Sikament 100SC has higher compressive strength at 28 days as compared to those mixed with starch. For this first part of the project only data gathering is done and considering it is an on going project there. The result or outcome of this project is found to be as below.

- Samples using Sikament 100SC produced a better compressive strength compared to concrete using natural starch based material.
- Samples using starch is able to increase viscosity of fresh at low dosage.
- Concrete incorporating starch dropped at different height has consistent compressive strength compared to those using Sikament 100SC.
- Compatible with other admixture (Water reducing admixture and superplasticizer) so that the rheology of the mix is not significantly altered, set is not drastically extended, and air entrainment or foaming is produced.

The natural admixture used should be able to have similar properties of those synthetic admixtures. Since the project is still on going it is still early to comment on the results. Nevertheless some of the progress has taken place such as preparation of water tank and the synthetic anti washout admixture has taken place.

However the concrete mix containing starch is better compared to samples without any anti washout material. It is concluded that the concrete mix containing chemical antiwashout performs better than starch. It is able to hold the cement and the aggregate together and not contaminating the tank.

Good quality underwater concrete is obtained through a continuous placement at a constant placement rate. Any prolonged interruption in concrete placement imposes high risks for defective concrete. Efforts should be made to ensure adequate and continuous concrete supply to the placement. The location of a concrete batch plant is also an important consideration in logistics planning and has a significant impact on construction cost, risk, and quality control.

An on-site batch plant has the main advantage of providing more reliable control of the concrete workability at the point of placement, because the time between concrete batching and placing is relatively short. This option, however, requires a significant investment in equipment.

• The tremie method is slow and prone to risk of segregation.

It is also found that the tremie method is a common technique for placing fresh concrete underwater. Concrete is poured from the surface through a hollow tube into a submerged form. This method has its disadvantages which are the following:-

- Pouring is controlled from the surface
- Strict control must be maintained to avoid segregation of the concrete.
- This method is limited in the depth to which concrete may be poured
- Separate formwork must be constructed and placed underwater
- The condition of the surrounding water must be calm.
- Delays in pouring cause concrete mix to harden inside the pipe.

5.2 RECOMMENDATION

For future purpose it is also important practice proper concrete production, supply, and placement to achieve high quality concrete and cost-effective construction. The choice of a proper underwater concreting plan for a project has to be ultimately determined by site conditions, engineering requirements, availability of equipment and contractor's preference.

Future recommendation experiment carried out can be done on wave water surface. This is because many underwater structures are subject to wave.

Apart from using starch the usage of other natural ingredient that has fine particle size can also be incorporated into the admixture to increase the viscosity of the concrete. From the observation made tremie process has its disadvantages. Future experiment is recommended to try other method that is feasible and easy to work with. The summaries of recommendations are as follows:-

- Avoid delays in pouring concrete during tremie process.
- Conduct experiment in wave tank to simulate actual situation when doing underwater concrete.
- Use mechanical mixer to allow admixture to mix thoroughly.
- Conduct experiment on the porosity of the underwater concrete.
- Compaction should be done underwater to if necessary.

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